# Chapter 4
# Sector Gates

## 4-1. Sector Gates

*a. Skin plate and vertical ribs.*

(1) Skin plate. The skin plate is designed as a continuous member supported by vertical angles of tees, with the calculated thickness being increased by one-sixteenth for corrosion loss. Normally, 3/8-in. total thickness or a design thickness of 5/16 in. is sufficient for the entire height of the gate. The allowable stress is 0.50F for basic loading conditions with a permissible increase of one-third for abnormal loading conditions. The edge of the skin plate should not be turned back on a radius to the horizontal beam. (See Plates B-34 through B-36 for additional information.)

(2) Vertical ribs. The skin plate is attached to vertical ribs, usually angles or tees, by continuous welds. These ribs are designed as continuous members supported by the horizontal beams. The skin plate is considered as an effective part of the vertical ribs, with the effective width of skin plate determined according to the AISC specifications. The minimum depth of ribs should be 8 in. to facilitate painting and maintenance, with design loads consisting of water load only.

*b. Horizontal beams*. The normal gate leaf has three horizontal beams supporting the vertical ribs and skin plate. Each beam is designed for water load and a combined water and boat load. The minimum depth of horizontal beams is 2 ft-0 in. out-to-out of flanges. The beam is designed as a continuous member supported by the horizontal struts and braces at midpoint between the struts. The curve of the beam can be neglected, with the length used for design equal to the arc length along the center line of the beam.

(1) In order to reduce the effect of dead-load eccentricity on the horizontal beams, the vertical members of the center and recess-side vertical trusses may be framed into the webs of these beams as shown in Section A-A, Plate B-34. The vertical member of the channel-side vertical truss should be attached to the downstream flanges of the horizontal beams as shown in Plan, Plate B-34, to reduce operating forces required during opening of the sector gate under reversed head conditions. Based on model test results published in Technical Report H-70-2 and Appendix A to this report (see USAEWES 1970, 1971) the framing method described above is recommended for new sector gates.

(2) Numerous existing sector gates are framed as shown in Plate B-35 where horizontal ribs are used to support the skin plate. The horizontal beams consist of straight members, with a length equal to the chord length determined by one-half the interior angle of the gate leaf. The beam is assumed to be a continuous beam of two equal spans, with the center support being braces from the horizontal struts. This type of framing is not recommended for new construction. The boat load applied to members of the leaf normally consists of 125,000 lb applied as a single concentrated force.

*c. Frames*. The basic sector gate leaf frame consists of three horizontal trusses and three vertical trusses, with horizontal and vertical trusses having some common members. The top and center horizontal frame, consisting of three horizontal struts and related bracing, forms a truss that is designed for water and boat load, with the concentrated boat load of 125,000 lb being applied at any point on the horizontal beam and at any panel point on the canal side of the truss. The bottom frame, or horizontal truss, is designed for water load only, assuming no boat impact at this level.

(1) The vertical trusses are designed for dead load and boat load, with the concentrated boat load of 125,000 lb being applied at the top corner and the center panel points. The vertical trusses are also designed for a combination of dead load and concentrated boat load applied at the panel points on the canal side of the leaf, with the boat load applied at the elevation of the top frame or the center panel point. The top horizontal members of the channel and recess side vertical trusses are also designed to support the walkway loads.

(2) The interior angle of the horizontal frames can vary from 60 to 70 deg, with the 70-deg angle preferred for 84-ft locks and larger.

(3) Rather than segmenting the gate leaf into horizontal and vertical trusses necessary for a manual solution, it is now practical to design and analyze sector gates as three-dimensional space frames utilizing available computer programs.

*d. Hinge assembly*. The hinge bracket and the hinge bracket support are made of cast steel or a weldment. The hinge bracket support is connected to the lock wall with bolts, prestressed to slightly more than the maximum tension load obtained from dead load and the maximum reverse head.

(1) The adjustment of the hinge assembly is provided between the embedded hinge bracket support and the hinge bracket section containing the pin barrel. Shims are used to adjust the gate leaf both horizontally and transverse to the axis of the lock. The bolts should extend into the concrete a sufficient depth to transfer the gate leaf load to the concrete, keeping the stress in the concrete within the range of 600 psi. The bolts should have an anchor frame or other positive means of transferring the forces to the concrete, assuming all of the transfer is made through bearing on the frame and none through bond on the bolts. The pin barrel segment of the hinge bracket should be designed as a curved beam similar in analysis to the gudgeon pin barrel described in paragraph 3-5 on horizontally framed gates. The pin barrel should be provided with a bronze bushing, with the bearing stress kept below 1,500 psi.

(2) The hinge pin may be made of forged steel or corrosion-resisting steel, depending on the location of the lock in relation to corrosive elements. Suitable means of lubricating the pin shall be provided either through the pin or with a grease fitting through the pin barrel and bushing. (See Plates B-37 and B-38 for suggested details.)

*e. Pintle assembly.*

(1) Pintle. The spherical pintle has proved to be the most satisfactory type for sector gates. This type of pintle has the advantage of allowing the gate leaf to tilt slightly without binding and also facilitates the replacement of the gate leaf after it has been removed for maintenance or repair. The pintle is designed for the maximum reaction, consisting of the combined water, boat, and gate dead loads.

(a) Corrosion-resisting steel is indicated by past design to be the most suitable material for the pintle where salt or brackish water is encountered.

(b) The pintle shaft, the cylindrical shaped lower segment of the pintle, extending 1 ft 3 in. to 2 ft 1 in. below the curved surface of the pintle, fits into a recess in the pintle base. This section of the pintle is designed for shear and moment as well as bearing on the pintle based between the pintle shaft and pintle base. The end of the pintle shaft is a flat surface that bears directly on the bottom of the recess in the pintle base.

(c) A seal should be provided at the lower edge of the pintle bushing to seal between the bushing and the pintle shaft.

(2) Pintle bushing. The pintle bushing, made of bronze, Alloy 913, Federal Specification QQ-C-390B, is made in two parts, with the plane of the vertical joint placed at 90 deg to the horizontal reaction of the gate. Grease grooves are provided in the bushing along with a suitable means of lubrication. The bushing is so connected to the pintle socket so that rotation between the socket and bushing is eliminated.

(3) Pintle socket. The pintle socket is made of cast steel and is the common point of intersection of the vertical pipe column between the pintle and hinge pin, the lower horizontal struts, and the diagonal chord members of the vertical trusses. The connections of members to the pintle housing are normally made by welding.

(4) Pintle base and anchorage.

(a) The pintle base and anchorage have the same function as the pintle base of miter gates, that is to transfer the horizontal and vertical forces of the gate leaf to the mass concrete. The pintle shaft fits into a recess in the pintle base, and through a combination of direct stress, bending, and shear, the force is transferred from the pintle to the pintle base. The base, in turn, transfers the force into the concrete. A grillage of small beams, normally in the range of an 8-in.-wide flange, is used to transfer the shear and distribute the bearing into the concrete. Anchor bolts are placed in first-pour concrete with the base placed in second pour. The base may be made of cast steel or a built-up weldment. In some cases, anchor bolts, prestressed to compensate for slightly more than the design forces, may be used to hold the pintle base in contact with the concrete. These bolts will be so located and prestressed that a compressive force will exist between all parts of the pintle base and the concrete under all loading conditions. Where prestressed bolts are used the grillage of beams may be eliminated. See Plate B-37 for typical details of pintle and pintle base.

(b) An alternate pintle anchorage design and details may be used as shown in Plate B-38. This design eliminates the grillage beams and assumes that the concrete in contact with the pintle pedestal base is not stressed. The pintle forces (direct stress, bending, and shear) are transmitted into the concrete through the anchor bolts.

*f. Seals*. The vertical seals on sector gates usually consist of a pair of 3-seals for the gate closure at the center of the lock and a single 3-seal attached to the corner of the gate recess. The seals at the gate closure, with one seal on each leaf, are presently 1/8 in. each seal, for a total of 1/4 in. to assure a minimum amount of leakage when the gate is closed. The recess seal is also set so as to have 1/4-in. compression when the gate is closed. On the recess seal the vertical plate, or angle, at 90 deg to the skin plate, should not extend over 6 in. from the skin plate and a lesser extension is preferable. The bottom seal utilizes an offset "J" seal, with the bulb offset upstream, or away from the convex side of the skin plate. Normal procedure is for the corner, where the bottom seal meets the vertical seal at the miter point, to be fabricated integrally with the bottom seal. (See Plate B-36 for typical details of all seals.)

*g. Walkway*. Access around the perimeter of the gate leaf and across the lock is provided by walkways mounted on top of the gates. On the recess and skin plate sides the overall width of walkway should be 3 ft 0 in., with 2 ft 8 in. center-to-center of rails. On the channel side, where a greater width is necessary for the transfer of maintenance equipment, the overall width should be 4 ft 0 in., with 3 ft 8 in. center-to-center rails. The dimensions given are for normal conditions and may be varied for unusual circumstances. Design loads should be 100 psf for the recess and skin plate walkway and 150 psf for the channel-side walkway. Grating is preferred over the raised pattern floor plates unless special circumstances warrant the use of plate. When grating is selected, type II, hot-dip galvanized after fabrication, should be used for most applications, with a minimum depth of 1-1/4 in. for bearing bars. Grating panels should be made in convenient size panels for installation and removal. Where raised pattern floor plate is used instead of grating, consideration should be given to hot-dip galvanizing for corrosion resistance and minimum maintenance. Handrail should be provided for all walkways, using 2-in. diameter extra-strong post with 2-in. standard pipe rail in conformance with paragraph 2-1*n*. Where special loading conditions are present the size of rail and post may be varied accordingly. Generally, the railing should be removable and made in convenient size panels to facilitate removal without equipment.

*h. Fenders, lifting supports, and gate stops*.

(1) Fenders. Timber fenders should be utilized on the canal side of all gate leaves to facilitate the distribution and absorption of barge or boat impact. The usual fender system is of 8-in. by 12-in. white oak timbers bolted to vertical beams, which in turn are connected to horizontal beams or girders. The horizontal beams are connected to the vertical members of the canal-side vertical truss. The timber should be surfaced all four sides, with bolts recessed into the timber a minimum of 1 in. The minimum size bolts used to support the timbers should be 3/4 in. in diameter. Under normal circumstances the horizontal timbers should be spaced 2 ft 0 in. on center, with the top timber placed on the center line of the top horizontal strut. The timber protection system should extend to or slightly below the minimum water level to be encountered during operation.

(2) Lifting supports.

(a) Jacking pads should be provided on the bottom of the gate leaf, located at panel points of the vertical trusses. The pads should be so located that the full weight of the gate can be supported by the pads while maintaining the gate in a stable position. A minimum of three pads should be used on each leaf.

(b) Lifting lugs on top of the gate should be considered for complete removal of the gate from the lock. These lugs should be so located that a standard three-leg bridle sling can be used to lift the gate leaf in the normal position. Lugs should be located on the vertical truss panel points if possible.

(3) Gate stops. Timber bumpers should be provided to prevent damage to the gate leaf caused by the leaf being forced against the wall of the recess. Under normal conditions three bumpers are used for each leaf, with the top bumper placed below the operating rack or cables and the middle and lower bumpers placed on the center line of the respective horizontal trusses or frames. The bumpers should be made of 6- by 10-in.-white oak timbers approximately 2 ft 0 in. long, with each bumper attached to the vertical beam adjacent to the skin plate with four corrosion-resisting bolts. Each timber on the leaf has a companion bumper attached to the wall of the recess, with each pair of bumpers having matching alignment. The recess bumper is also attached with a minimum of four corrosion-resisting bolts, extending approximately 1 ft 4 in. into the concrete with an additional 3-in. standard hook. The bolts should be so spaced that the bolts in the timber on the leaf are not in line with the bolts in the timber recess. All bolts should be recessed to provide a minimum of 1 in. between the head of the bolt and the face of the timber. (See Plate B-36 for a typical detail.)

*i. Embedded metals*. The items normally included in this category are hinge anchorage, pintle base and anchorage, seal beam for the bottom seal, and the embedded plate which supports the side seal beam. The hinge anchorage and pintle base and anchorage have been discussed in previous paragraphs.

(1) The seal beam for the bottom seal normally is made up of a rolled beam with a corrosion-resisting plate attached to the top flange. The top of the corrosion-resisting plate is flush with the floor of the lock. The beam should be placed in second-pour concrete with anchor bolts, also used for adjustment, extending into first-pour concrete.

(2) The embedded plate which supports the side seal beam is located at the corner of the gate recess. This plate should be made of structural steel and should be anchored with bolts set in the first-pour concrete. The side seal beam should be bolted to the embedded plate with corrosion-resisting bolts. The seal contact of the beam should be clad with corrosion-resisting material. See Plate B-36 for typical details of side seal and bottom seal embedded metal.

*j. Cathodic protection.* Primarily two basic types of cathodic protection systems are used on sector gates. One system, using sacrificial anodes, is the least efficient of the two systems but has a lower initial installation cost. Another disadvantage of the sacrificial anode system is that the gate leaf has to be removed or dewatered for maintenance or replacement of anodes. Impressed current cathodic protection should be used on sector gates. See Chapter 7 for additional information on cathodic protection.

(1) The other system, commonly known as the impressed current system, has a higher initial installation cost but is more efficient than sacrificial anodes. Button-type anodes used with this system have the same disadvantages as the sacrificial anodes for maintenance and replacement.

(2) The thickness of the skin plate should be increased 1/16 in. and cathodic protection omitted from the convex face of the skin plate. This allows a better side seal as the seal can be placed closer to the skin plate of the leaf.

(3) Where possible to schedule the gates for removal or dewatering for maintenance and painting (at intervals not to exceed six years), sacrificial anodes should normally be used in lieu of the impressed current system unless more severe corrosive elements indicate the need for a more efficient system. When time intervals between dewatering exceed six years impressed current should be used.

(4) Where the corrosive elements of the water require a more efficient system of cathodic protection the impressed current system may be used, utilizing string-type anodes that can be removed or replaced without dewatering or removing the gate.

(5) See Chapter 7 for additional information on cathodic protection.

k. *Erection and testing.* The same general procedures that were discussed for horizontally and vertically framed gates should apply to sector gates. Each gate leaf should have the same shop assembly and matchmarking as well as the same general allowable tolerances.

(1) The gate leaves should be erected in position on the pintle and temporary supports the same as horizontally and vertically framed gates. The clearances of the gate leaves above the lock floor may preclude the use of temporary concrete pedestals for erection.

(2) All items covered under miter gates herein should apply to sector gates with the exception of diagonals and zinc or epoxy filler. The remaining comments on erection, trial operation, and workmanship should be applicable to sector gates as well as miter gates.

## 4-2. Operating Machinery

*a. General description.* The sector gate is generally operated by machinery similar to the electric-motor-driven miter gate machinery. The machinery used normally consists of a hydraulic motor or an electric motor, a herringbone gear speed reducer, a specially designed angle drive gear unit, an electrically operated brake, limit switches, and other accessories connected so as to drive a large radius rake which is bolted to the top upstream edge of the gate. A general arrangement is shown in Plate B-54. An alternate machine utilizing a cable and drum arrangement can be used to pull the gate in and out of the recess. This arrangement is shown in Plate B-55. The machinery components would be similar to the gear machine except that a drum and cable would be utilized in lieu of the pinion and rack.

*b. Design considerations and criteria.*

(1) General. Difficulty was experienced in the design of the first sector gates when operating under reverse heads. Prototype tests showed that the

hydrodynamic and friction forces were much greater than anticipated in the design. The normal operating forces on sector gates are primarily caused by friction on trunnion and hinge pin, forces on seal bracket, bottom friction, and hydraulic loads. Extensive tests have been made to obtain operating forces on sector gates. These tests, made by the Waterways Experiment Station (WES), have been published in Technical Report H-70-2 and Appendix A to the report (USAEWES 1970, 1971). Subsequent tests made by WES resulted in the design of a new improved gate with operating forces approximately 20 percent of those experienced in the original designs.

(2) Machinery components. Under normal heads, sector gate tests have shown that the loads created by flowing water tended to close the gate but were considerably less than those observed under reverse heads. Under all reverse head conditions, loads imposed on the gate by the flowing water tended to close the gate. Loads increased with gate openings up to 5 to 7 ft then showed a tendency for a slow decrease at greater openings. Model data for gate openings of about 6 ft can be used to predict peak torque for various lower pools and reverse heads. Model and prototype tests demonstrated that the major loads on the gate are caused by structural members in the immediate vicinity of the skin plate at the miter noses of the gate leaves and by the side seal bracket that blocks side flow at the recess edge of the skin plate. Timber fenders, which are offset from the skin plate, have a very negligible effect on forces. General criteria applicable to machine components are presented in paragraph 1-11.

*c. Determination of machinery loads.* When determining operating loads for a sector gate, Technical Report H-70-2 and Appendix A to the report (USAEWES 1970, 1971) should be used as a guide. However, if a gate design varying considerably from the type shown in the report is used, model studies to determine the loads should be performed.

(1) After maximum operating conditions on the sector gates have been determined, the gate operating loads should be computed both for normal flow and for reverse flow conditions. Due to the construction of the bottom seal no bottom seal friction is created during reverse heads. Loads due to reverse head conditions will usually establish the size of machine to be used; however, loads due to normal heads should be checked.

(2) Water load on the gate will be created by the projected width of miter beam, skin plate rib, and seal bracket. Figure a, Plate 44 of Technical Report H-70-2, Appendix A, gives the peak closing pintle torque for the improved type gate. These torque curves are reproduced for this manual and are shown in Plate B-81. This torque is based on a gate having a total projected width of miter beam, skin plate rib, and seal bracket of 30.375 in. (17.875 in. + 8 in. + 4.5 in. = 30.375 in.). The torque taken from Plate B-82, Sheet 2, should be corrected in accordance with Froude’s law of similarity to the lengths used on the proposed gate based on the scalar ratio. Hinge friction and pintle friction torque should be added to the above water load to determine the total machinery load. Reference should be made to Miscellaneous Paper H-71-4, paragraph 14 (USAEWES 1971), in conjunction with establishing reasonable values of hinge and pintle friction. Typical calculations for determining loads on the improved type of sector gate are shown in Plate B-82, Sheets 1-3.

*d. Operating machinery controls.* Sector gates are usually controlled from a small control house located adjacent to each pair of gate leaves. For electric motor drive, the control equipment consists of the combination of full voltage magnetic controllers, limit switches, control pushbuttons, and switches arranged to produce the desired operating sequence. For fluid motor drive, the speed of the gate is varied by controlling the flow of oil to the fluid motor either by throttling or by use of a variable stroke piston pump. With this system, control valves can be either manually or electrically controlled.